Claims

1. An ultrasound phased array imaging system comprising:

a probe (10) with a 2-D array of transducer elements (12) for acquiring 3-D ultrasound data of a volume of a body, including moving tissue and fluid flow;

a beamforming system (10, 12, 14, 16) for emitting and receiving in real time ultrasound beams in said volume, which acquires, in real time and in 3-D, more than one spatial receive beams signals for each transmission beam within an ensemble length of more than two temporal samples, among which the receive flow beam signals and the receive tissue beam signals are substantially temporally uncorrelated but spatially correlated;

separation means (30) comprising adaptive spatial tissue filtering means, using simultaneously more than one spatial receive beam signals acquired in 3-D within the ensemble length of more than two temporal samples, for analyzing temporal variations of the respective successive receive signals and for extracting flow receive beam signals from spatial combinations of receive beam signals;

processing means (40, 50) and display means (62, 60) for processing flow Doppler signals and for displaying images based on said processed flow Doppler signals.

2. The ultrasound phased array imaging system of claim 1, wherein the filtering means comprises calculations means for:

calculating an auto-correlation function of temporally correlated and spatially uncorrelated tissue and flow receive signals,

calculating a spatial correlation diagonal matrix from said autocorrelation function, and

separating the temporally uncorrelated Doppler components corresponding to flow and tissue signals from said diagonal matrix.

3. The ultrasound phased array imaging system of one of Claims 1 or 2, wherein the filtering means extracts the receive flow Doppler signals from spatial combination of receive beam signals using simultaneously four to sixteen or more spatial receive beam signals acquired in 3-D within an ensemble length of three, four or more temporal samples.

4. The ultrasound phased array imaging system of one of Claims 1 to 3, wherein, in order to enhance spatial resolution of the extracted 3-D receive flow Doppler signals, receive

beams signals are simultaneously acquired corresponding to receive beams formed according to a regular scheme and are simultaneously processed by couples corresponding to two adjacent receive beams, or by sets corresponding to several grouped receive beams, to provide supplementary spatial motion estimations at spatial positions between the beams of the couples or at the centers of the grouped beams.

5. The ultrasound phased array imaging system of one of Claims 1 to 4, wherein, in order to enhance resolution of the extracted 3-D receive flow Doppler signals, sixteen receive beams signals are simultaneously acquired, corresponding to receive beams disposed according to a square scheme, and are simultaneously processed:

by couples of receive beam signals corresponding to two adjacent receive beams, forming twenty-four couples, to provide twenty-four spatial motion estimations (M1-M24), respectively at twenty-four spatial positions between the beams of the couples; and/or

by quadruplets of receive beam signals corresponding to four (2x2) receive beams forming a square, forming nine quadruplets to provide nine spatial motion estimations (N1-N9), respectively at spatial positions at the center of the squares formed by the beams of the quadruplets;

for providing nine to thirty-three supplementary motion estimations to the sixteen motion estimations.

6. The ultrasound phased array imaging system of one of Claims 1 to 5, comprising:

demodulation means (18), which computes complex data signals (4xI,Q) from each of four to sixteen or more receive beam signals;

separation means (30), which separates complex data signals of moving tissue from complex data signals of fluid flow, using an ensemble length of at least three successive transmissions along an emission beam direction to analyze temporal variations of the respective successive receive signals;

processing means (40, 50) for processing the extracted complex data signals of fluid flow to provide fluid flow information data;

and display means (62, 60) to process fluid flow information data and to display images based on said processed fluid flow information data.

7. The ultrasound phased array imaging system of Claim 6, wherein the processing means comprises:

a Doppler shift estimate (40, 41) for estimating Doppler velocity from the extracted complex data signals of fluid flow;

a color flow velocity processor (50, 51) for mapping flow velocity values on color values;

and/or:

a Doppler power estimate (40, 42) for estimating Doppler power magnitude from the extracted complex data signals of fluid flow;

a color power processor (50, 51) for mapping the estimated power magnitude on color values.

8. The ultrasound phased array imaging system of one of Claims 6 or 7, comprising:

a B mode processor (61) for processing the amplitude information of the echo signals (RF), on a spatial basis, for the formation of structural images of the tissue.

9. The ultrasound phased array imaging system of one of Claims 6 to 8, comprising:

a display processor for processing the B mode data, color flow velocity data, color power data, and an image memory for memorizing the image data for display; and

a user control (65) for the user to select the images to display in one mode or in combined modes.

10. An ultrasound imaging method comprising steps of:

acquiring 3-D ultrasound data of a volume of a body, including moving tissue and fluid flow;

emitting and receiving ultrasound beams in said volume, comprising acquiring, in real time and in 3-D, more than one spatial receive beams signals for each transmission beam within an ensemble length of more than two temporal samples, among which the receive flow beam signals and the receive tissue beam signals are substantially temporally uncorrelated but spatially correlated;

separating receive flow Doppler signals means from receive tissue Doppler signals with adaptive spatial tissue filtering, using simultaneously more than one spatial receive beam signals acquired in 3-D within the ensemble length of more than two temporal samples, for analyzing temporal variations of the respective successive receive signals and for extracting flow receive beam signals from spatial combinations of receive beam signals;

processing flow Doppler signals and displaying images based on said processed flow Doppler signals.

11. The ultrasound imaging method of claim 10, comprising steps of:

calculating an auto-correlation function of temporally correlated and spatially uncorrelated tissue and flow receive signals,

calculating a spatial correlation diagonal matrix from said autocorrelation function, and

separating the temporally uncorrelated Doppler components corresponding to flow and tissue signals from said diagonal matrix.

12. The ultrasound imaging method of one of Claims 10 or 11, comprising steps of:

simultaneously acquiring receive beams signals corresponding to receive beams formed in a regular scheme;

simultaneously processing said signals by couples corresponding to two adjacent receive beams, or by groups corresponding to several receive beams, to provide supplementary spatial motion estimations at spatial positions between the beams of the couples or at the centers of the groups.

13. A computer program product comprising a set of instructions for carrying out a method as claimed in one of Claims 10 to 12.